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(54) TV cameras; inspecting a subject in a turbid medium

(57) An underwater TV camera 1 for use in turbid water conditions transmits pulses of light from a laser 4 and receives the light after reflection from a subject 2 using a conventional TV camera 7. A range gate 5 allows the TV camera to view subjects only within a defined range gate. Instead of opening the range gate 5 for periods equal to the duration of the flashes of light it is allowed to remain open for longer periods thereby improving the field of view. Because of the turbid conditions, this does not degrade to signal-to-noise ratio as much as would be expected in conditions of good visibility.

The system may also be applied to ultrasonic cameras and inspection devices, for use in fog or in a radar system.

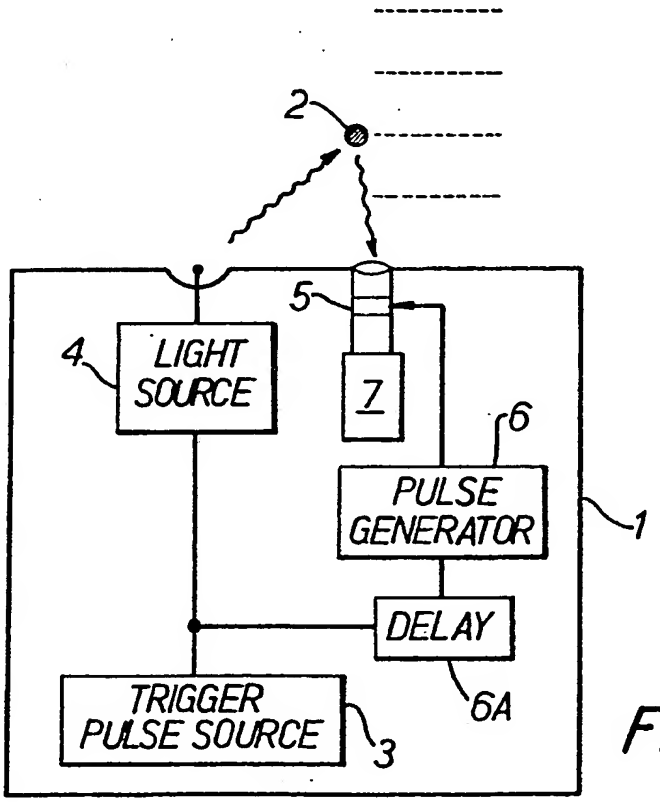

FIG. 1.

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The drawing originally filed was informal and the print here reproduced is taken from a later filed formal copy.

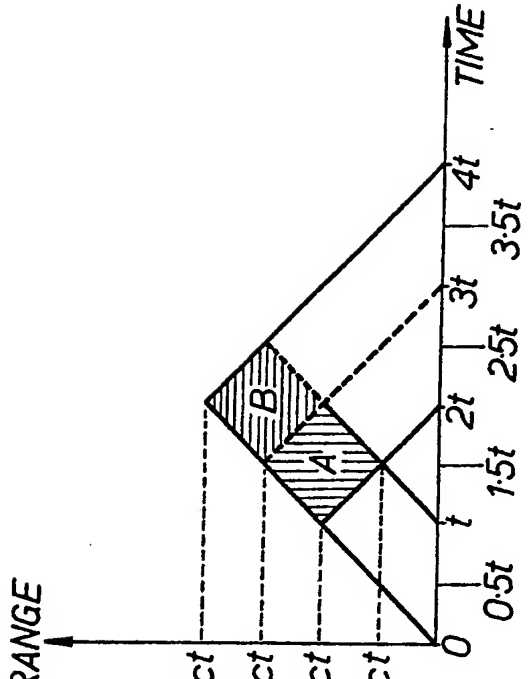
TIME
RANGE
B
A
0
0·5t
t
1·5t
2t
2·5t
3t
3·5t
4t
-2ct
-1·5ct
-ct
-·5ct

FIG. 2.

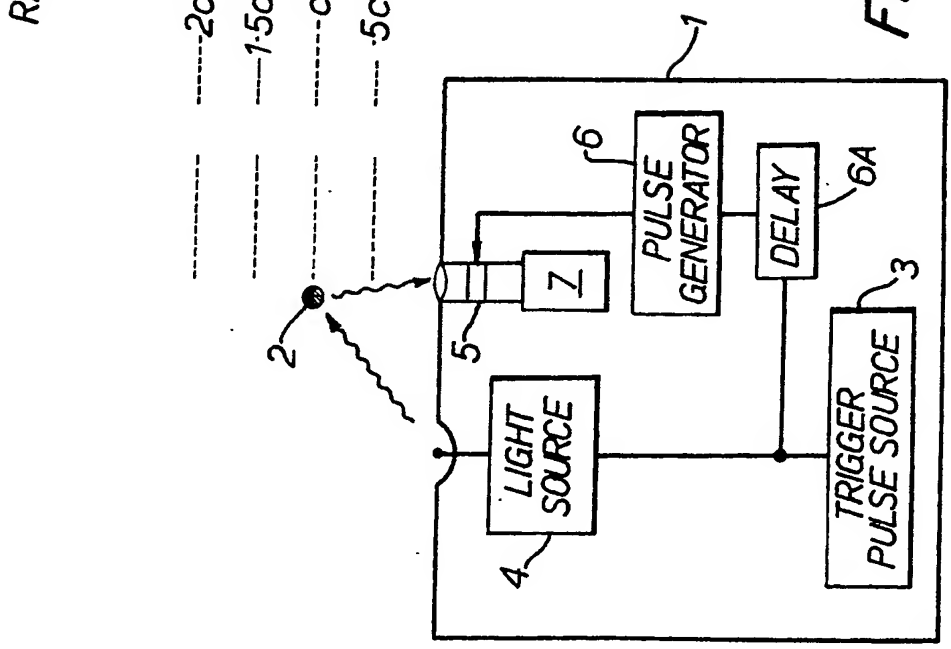
1
2
5
Z
6
PULSE GENERATOR
DELAY
6A
3
TRIGGER PULSE SOURCE
LIGHT SOURCE
4

FIG. 1.

SPECIFICATION

TV cameras and other apparatus for inspecting a subject in a turbid medium

This invention relates to a method and apparatus for inspecting a subject in a medium which is not perfectly transparent. It is particularly applicable to underwater television cameras operating at optical and/or infra-red wavelengths but could be applicable to television cameras for use in fog and to many other fields such as ultrasonic cameras and inspection devices and radar.

When television is used in turbid water with a set of lights to illuminate the scene, the back scatter from particles suspended in the water severely limits the range of operation. This is because the amount of light received after reflection from the suspended particles is large compared with the light received from a subject under inspection. The difficulty is analogous to the difficulty of driving by headlights in fog. One proposal for overcoming this problem of extending the operational range is to use short pulses of light in conjunction with a time gated TV camera. The length of the transmitted light pulse is selected according to the need for a minimum range of operation or according to the depth of field that is required to illuminate the object being viewed. Such a system is conveniently called "range gated television" as it is not sensitive to objects and scatterers that are at substantially different ranges from the subject under inspection.

The normal training of engineers leads them to the use of a matched receiver that gives the optimum signal-to-noise ratio at the output. To achieve this it is necessary to match the length of time that the receiver is open to the length of time that the illumination is on. The difference between the occurrences of the two time periods is dependent on the velocity of propagation in the water and the range of the object of interest. This principle has also led to the belief that it is necessary to use a sequence of range gates in order to produce an image that has a much larger depth of field than would be obtainable with a single range gate. This view is quite true at long ranges which may be conveniently defined as where the range of interest is much greater than the length of a single range gate that would match the light pulse.

This invention arose when the inventor realised that, at short range, such as a very few range gate lengths, an overall advantage on a balance of depth of field and the contrast against the background may be obtained by mismatching the length of the receiver range gate. This mismatching is made as an extension of the receiver range gate. This is permissible as the predominant source of back scattered light is that due to the short range scatterers as the light to and from the longer range scatterers suffers severe attenuation due to the longer light path. The significance of this difference in attenuation is far greater where the range is covered by a range gate of a wide ratio of maximum to minimum range i.e. at short overall ranges rather than at longer ranges.

This invention provides apparatus for inspecting a subject in a medium comprising means for transmitting a pulse of radiation into the medium and receiving it after reflection from a particular range cell defined by the apparatus; characterised in that the period of reception is longer than the period of transmission.

The invention also provides a method of inspecting a subject in a medium comprising transmitting a pulse of radiation into the medium and receiving it in a receiver after reflection from a particular range cell which is defined by the receiver and is sufficiently close to the apparatus that radiation received from reflective material in the closest part of the range cell is substantially more intense than from reflective material at the farthest part; characterised in that the period of reception is longer than the transmitted pulse.

Because the period of reception is longer than the transmitted pulse an improvement in the depth of field is obtained for a pulse of a given duration without a proportional degradation of the signal-to-noise ratio.

The apparatus may be a camera such as a TV camera operating at optical and/or infra-red wavelengths and incorporating suitable focussing means for producing an image of the subject.

The apparatus can include means for receiving the transmitted pulse after reflection from a plurality of different range cells either contiguous or overlapping. In such an arrangement the invention reduces the number of different range cells required by increasing the range bracket of each cell; thereby reducing the complexity of the system. Preferably cells at larger ranges will occupy smaller range brackets since the advantages of the invention in providing a large range bracket are reduced as range increases and the conventional principles of matching the range bracket to the length of the transmitted pulse become more important. In an alternative arrangement, instead of providing a plurality of different range cells, it would be possible to arrange for the apparatus to be adjustable to vary the range cell to be viewed at any one particular time.

One way of performing the invention will now be described by way of example with reference to the accompanying drawings in which:

Figure 1 is a schematic view of a remotely operated underwater vehicle 1 viewing an object 2 and equipped with a range gated television camera; and

Figure 2 illustrates a graph of range against time of a pulse of light of duration t transmitted and received by the apparatus of Figure 1. The range scale of Figure 2 is aligned with Figure 1 so as to indicate on Fig. 1 the range of the object 2 from the vehicle 1.

Referring to Figure 1, a vehicle 1 is located in turbid water and is positioned to inspect a subject 2 of interest. The vehicle 1 includes a trigger

source 3 which produces a series of pulses which trigger a source of illumination 4 to produce flashes of duration t. The first flash, occupying a period 0-t is shown in Figure 2. The source 4 in this particular embodiment of the invention is a laser. However, in alternative embodiments it could be a conventional photographic flash tube the optical output of which is gated if necessary by a suitable optical gate controlled by the pulses 3. A Kerr cell 5 is opened for a period after transmission of the light pulse by a pulse received from a generator 6. This is initiated by the trigger pulse from 3 after a delay imposed at 6A. During the period when the Kerr cell is open light from the transmitted pulse and reflected off the subject and suspended particles enters a TV camera 7.

Conventional principles require that the period of opening of the Kerr cell 5 be equal to the period of the light pulse: namely t seconds. Therefore, to inspect the subject 2 at a range ct the gate would be opened for a period 2t to 3t. This would ensure that the whole of the pulse would be received after reflection from range ct. Part of the pulse would be reflected from particulate matter at other ranges between 0.5 ct and 1.5 ct. Such reflected energy may be considered as noise and conventional principles would dictate that this is proportional to the turbidity and to the area of part A of Figure 2 indicated with vertical cross hatching. Thus the opening of the range gate during the period 2t to 3t optimises the signal-to-noise ratio since it minimises the noise whilst still receiving the whole of the pulse from the range ct under inspection.

The inventor has realised that, at short ranges, such as that illustrated on Figure 2 where the range of the subject 2 is of the same order of magnitude as the distance ct occupied by the light pulse, the noise is not in fact proportional to the area A. In fact the vertical cross hatched area above the line ct will contribute a smaller amount of noise than the area below the line. This is because, at small overall ranges, relatively distant regions will be illuminated weakly compared with relatively close ranges; the light being attenuated with distance because of the turbidity of the water. Thus, in accordance with the invention the gate 5 is opened for a period extended beyond time 3t to a time such as shown at 4t. This results in the advantage of extending the depth of field of the camera since the whole of the pulse is now received after reflection from subjects between ranges ct and 1.5 ct: whilst not appreciably reducing the signal-to-noise ratio because the noise arising from the area B shown with horizontal cross hatching contributes only a small amount of noise, being at relatively large range.

CLAIMS

1. Apparatus for inspecting a subject in a medium comprising means for transmitting a pulse of radiation into the medium and receiving it after reflection from a particular range cell defined by the apparatus characterised in that the period of reception is longer than the transmitted pulse.

2. Apparatus according to claim 1 in which the radiation is light.

3. Apparatus according to any preceding claim including means for using the received radiation to form an image of the subject.

4. Apparatus according to any preceding claim including means for receiving and processing separately the radiation received from at least one further range cell more distant than the first-mentioned range cell and extending over a smaller range bracket.

5. Apparatus as substantially described with reference to the accompanying drawings and substantially as illustrated therein.

6. A method of inspecting a subject in a medium comprising transmitting a pulse of radiation into the medium and receiving it in a receiver after reflection from a particular range cell which is defined by the receiver and is sufficiently close to the apparatus that radiation received from reflected material in the closest part of the range cell is substantially more intense than from reflective material at the farthest part: characterised in that the period of reception is longer than the transmitted pulse.

7. A method according to claim 6 in which the radiation is light.

8. A method according to any one of claims 6 to 8 in which the medium contains reflective particles substantially evenly distributed through the said range cells.

9. A method according to any one of claims 6 to 8 in which the received radiation is used to form an image of the subject.

10. A method according to any one of claims 6 to 9 in which the radiation is received and processed separately from at least one further range cell more distant than the first mentioned range cell and extending over a smaller range bracket.

11. A method as substantially described with reference to the accompanying drawings.

New claims or amendments to claims filed on 23/2/84
Superseded claims: 1 to 11
New or amended claims: 1 to 10

CLAIMS

1. Apparatus for inspecting a subject in a medium comprising means for transmitting a pulse of radiation into the medium and receiving it after reflection from at least two particular range cells defined by the apparatus characterised in that the period of reception for the closer of the two cells is longer than the transmitted pulse and longer than the period of reception for the more distant of the two cells.

2. Apparatus according to claim 1 in which the radiation is light.

3. Apparatus according to any preceding claim including means for using the received radiation to form an image of the subject.

4. Apparatus substantially as described with reference to the accompanying drawings and

substantially as illustrated therein.

5. A method of inspecting a subject in a medium comprising transmitting a pulse of radiation into the medium and receiving it in a receiver after reflection from a particular range cell which is defined by the receiver and is sufficiently close to the apparatus that radiation received from reflective material in the closest part of the range cell is substantially more intense than from reflective material at the farthest part: characterised in that the period of reception is longer than the transmitted pulse.

6. A method according to claim 5 in which the radiation is light.

7. A method according to claim 5 or 6 in which the medium contains reflective particles substantially evenly distributed through the said range cells.

8. A method according to any one of claims 5 to 7 in which the received radiation is used to form an image of the subject.

9. A method according to any one of claims 5 to 8 in which the radiation is received and processed separately from at least one further range cell more distant than the first mentioned range cell and extending over a smaller range bracket.

10. A method substantially as described with reference to the accompanying drawings.

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